JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR 1998, **69,** 77–85 NUMBER 1 (JANUARY)

REINFORCER EFFICACY IN A DELAYED MATCHING-TO-SAMPLE TASK

RICHARD WEAVERS, T. MARY FOSTER, AND WILLIAM TEMPLE

UNIVERSITY OF WAIKATO, NEW ZEALAND

Five domestic hens were exposed to a delayed matching-to-sample task. Conditions 1, 5, and 8 were variable-delay conditions in which five delays (0.25, 1, 2, 4, and 8 s) from the red or green sample to the presentation of the red and green comparison stimuli were presented a number of times during each session. In the fixed-delay condition (Condition 3), each delay was presented for 15 sessions under a Latin square design across birds. When improvements in accuracy across the variable-delay conditions are taken into account, the data were similar under both the variable and fixed delays. In Conditions 2, 4, 6, and 7 sample–reinforcer intervals were held at 8, 8, 4, and 2 s, respectively, while sample–choice intervals were varied within these during each session. With increasing sample–reinforcer interval, both initial discriminability (i.e., with sample–choice delay = 0) and rate of decrement in discriminability decreased. Although the former would be predicted if accuracy depends of the average sample–reinforcer interval, the latter would not. These data show that increasing the sample–choice interval had less effect on matching accuracy than increasing the sample–reinforcer interval did.

Key words: delayed matching to sample, variable delay, fixed delay, sample–reinforcer interval, direct remembering, key peck, hens

A common delayed matching-to-sample (DMTS) task with animal subjects (e.g., White, 1985; White & Bunnell-McKenzie, 1985) is one in which a sample stimulus presented on a center key is followed, after a delay interval, by a pair of comparison stimuli presented on two side keys, usually with some reinforcer provided after a response to a matching comparison stimulus. Findings show that the proportion of DMTS trials on which a correct match is made systematically decreases with increasing delay interval (e.g., White, 1985; White & Bunnell-McKenzie, 1985; White & McKenzie, 1982).

Several theories have been proposed to account for this decrement in performance, or forgetting, ranging from Roberts and Grant's (1976) trace-decay hypothesis to White's (1993)[1] direct remembering account. If, however, one understands the DMTS task as involving delayed reinforcement for remembering behavior that may result in a correct choice of comparison stimulus, then the decrease in matching accuracy over time could be at least partly accounted for by the reduced effect of delayed reinforcement on sample-directed behavior. A well-documented aspect of reinforcer efficacy (e.g., Chung, 1965; Chung & Herrnstein, 1967) is that as reinforcement is increasingly delayed from the time of the behavior that it is dependent upon, the likelihood of occurrence of that behavior becomes increasingly reduced. In most DMTS procedures, the delay to choice and the delay to reinforcement are essentially the same (Wixted, 1989). However, it is possible within a DMTS procedure to separate these aspects to some extent.

McCarthy and Davison (1991) varied delay to choice using the usual DMTS procedure and, in another condition, held delay to choice at zero while varying the delay to reinforcement following correct choices. They provided these delayed reinforcers at the same times that they would have occurred in the usual delay-to-choice procedure. They found that a delay to reinforcement had an effect similar to a delay to choice, although it was not as pronounced. This result suggests that forgetting may be partly accounted for

Part of this experiment formed a dissertation submitted by the first author in partial fulfillment of the requirements for a MSocSc degree at the University of Waikato, Hamilton, New Zealand. We thank Jenny Chandler and the students at the Animal Behaviour and Welfare Research Centre, Hamilton, New Zealand, for their help in running this experiment.

Address correspondence to Richard Weavers, Department of Psychology, University of Waikato, Private Bag 3105, Hamilton, New Zealand (E-mail: Will@waikato.ac.nz).

[1] White, K. G. (1993, May). *Consequences of direct remembering.* Paper presented at the annual meeting of the Association for Behavior Analysis.

by lack of immediate reinforcement for remembering. McCarthy and Davison's procedure could not separate how much of the decrement in matching accuracy was due to sample–reinforcer interval and how much was due to increasing sample–choice interval, independent of the sample–reinforcer interval.

McCarthy and Davison (1991) used a fixed-delay procedure in which the same sample–choice and choice–reinforcer delays were in effect each session. White and Bunnell-McKenzie (1985) examined two ways of varying delay interval (sample–choice) duration: within a session and between sessions. Pigeons' behavior under a series of fixed-delay conditions was compared with that under a variable-delay condition (in which the same delay intervals were presented across trials in each session). Matching accuracy was better at all delays in the variable-delay condition. White and Bunnell-McKenzie suggested that improved accuracy at longer delays was a result of the average delay to reinforcement in the variable delays being less than in the fixed-delay procedure (cf. Carter & Werner, 1978). For example, if a subject is working in a fixed-delay condition with a delay interval of 10 s, the average delay to reinforcement (from sample-stimulus termination) is 10 s. If, instead, the subject is working in a variable-delay condition with half 1-s and half 10-s delay intervals, the average delay to reinforcement is 5.5 s. Because the average delay to reinforcement is smaller in the variable-delay case, performance following the 10-s delay should be better (cf. Wixted, 1989). White and Bunnell-McKenzie noted that this explanation did not account for the increased accuracy they found at the shorter delays in the variable-delay condition. According to the same explanation, accuracy should have been lower than fixed-delay accuracy at the shorter delay intervals.

The present study had two aims. First, it was an attempt to separate the effects of sample–choice and sample–reinforcer intervals on matching accuracy. It involved a series of variable-delay conditions, suggested by Jones (1988), in which the sample–reinforcer interval was held constant while the sample–choice interval was varied. This procedure allows further examination of McCarthy and Davison's (1991) findings. Their fixed-delay procedure showed that increasing the choice–reinforcer interval had an effect similar to but smaller than that of increasing both the sample–choice and sample–reinforcer intervals (as in the usual DMTS procedure). The variable-delay procedure used here should indicate how much of the decrement in matching accuracy is due to increasing sample–reinforcer interval and how much is due to increasing sample–choice interval, independent of the sample–reinforcer interval. Variable sample–choice delay conditions were conducted before, after, and in between the constant sample–reinforcer delay conditions for comparison. Second, the present study involved an attempt to replicate the results of White and Bunnell-McKenzie's (1985) experiment. To this end, a condition with fixed delays was included.

METHOD

Subjects

The subjects were 5 Star Shaver-cross domestic hens, numbered 71, 72, 73, 75, and 76, with some previous experience of DMTS. The hens were about 1.5 years old at the beginning of the study and were maintained at 80% ± 10% of their free-feeding body weights with supplementary feeding of commercially prepared food pellets. Grit and water were provided in the home cages.

Apparatus

The experimental chamber was a white chipboard box with internal dimensions 415 mm wide, 520 mm long, and 510 mm high. The front wall contained three opaque Perspex response keys, 32 mm in diameter, in a horizontal row 360 mm above the grid floor. All keys could be illuminated either red or green and required a force of at least 0.2 N to be operated. The food hopper was recessed below the center key. There was no houselight; the only illumination was provided by the response keys or the hopper light during 3-s wheat presentation. Experimental events were controlled by a remote MITAC® 386PC interfaced with a MED® programmable control board and operating MED 2.0® software.

Procedure

Sessions were conducted 6 days per week. Each session lasted for 40 trials, or was stopped if a bird had failed to complete 40 trials within 2,400 s. All subjects were presented with the same experimental conditions and daily sessions, except during the fixed-delay condition, which is explained below. Each trial in every session began with the illumination of the center key, either red or green at random (p = .5). The fifth peck on the center key darkened it and initiated a delay interval. During the delay interval the chamber was dark, and pecks to the response keys were ineffective. Following this delay, the two side keys were lit, one red and the other green at random (p = .5). A peck to the side key of the same color that the center key had last been was deemed to be a correct choice; a peck to the other key was deemed incorrect.

For Conditions 2, 4, 6, and 7, a further delay interval followed, so that the consequence of the comparison stimulus (side key) choice occurred a fixed time after sample stimulus (center key) termination (sample–reinforcer interval). For Conditions 1, 3, 5, and 8, the consequence of comparison choice was presented immediately following that choice response. The consequence of a correct choice was always 3-s access to wheat from the illuminated hopper. The consequence of an incorrect choice was always a 3-s blackout. Following either consequence was an intertrial interval (blackout) of 10 s; then the next trial started.

During Condition 1 the delay to choice varied from trial to trial and the reinforcer followed a correct choice immediately. One of five different delay intervals was randomly selected without replacement from the array 0.25, 1, 2, 4, and 8 s, for each of five trials. This procedure was repeated for the next five trials, until each delay interval had been presented eight times during a session. After performance was judged to be stable by inspection of graphs showing proportion of correct trials for each subject, at each delay, and by each session, 20 more sessions were conducted. The data from these last 20 sessions were used for analysis.

Condition 2 was similar to Condition 1, except that reinforcers following correct responses were not available until 8 s after completion of the response requirement (five pecks) on the center key. Thus, when the sample–choice delay was 8 s, reinforcement of a correct choice was immediate. When the sample–choice delay was 1 s, a correct choice response was reinforced 7 s later.

Table 1

Order of the fixed delays during Condition 3 for each bird.

Subject	Fixed delay (s)				
71	0.25	1	2	4	8
72	8	4	2	1	0.25
73	1	2	4	8	0.25
75	4	8	0.25	1	2
76	8	0.25	1	2	4

In Condition 3 (fixed delay) the same delay intervals were presented as in Condition 1; however, each session included only one delay interval throughout. Blocks of sessions in which the various delays were presented were arranged in a pseudo-Latin square design (after White & Bunnell-McKenzie, 1985) as shown in Table 1. Each block continued until each subject had completed 15 sessions, except that Subject 75 ceased responding after seven sessions in her 8-s block.

Condition 4 was a replication of Condition 2, and Condition 5 was a replication of Condition 1. Condition 6 (4-s sample–reinforcer interval) was similar to Condition 2, except that only the delay intervals of 0.25, 1, 2, and 4 s were included, and reinforcers occurred 4 s after sample termination. Condition 7 (2-s sample–reinforcer interval) was also similar to Condition 2, but with delay intervals of 0.25, 1, and 2 s, and with reinforcers occurring 2 s after sample termination. Condition 8 was a further replication of Condition 1. The details of the experimental conditions are summarized in Table 2, together with the number of sessions each was in effect. The conditions were conducted in numerical order.

RESULTS

For each bird, correct choices of comparison stimuli at each delay interval were summed over the last 20 sessions of each variable-delay condition and all 15 sessions of each fixed delay. The matching accuracy mea-

Table 2

The order of experimental conditions, the sample–choice and sample–reinforcer intervals, and the number of sessions each condition was in effect.

Condition	Sample–choice interval (s)	Sample–reinforcer interval (s)	No. of sessions
1	Variable (0.25, 1, 2, 4, and 8)	0[a]	52
2	Variable (0.25, 1, 2, 4, and 8)	8	52
3	Fixed (0.25, 1, 2, 4, and 8)	0[a]	15 per delay
4	Variable (0.25, 1, 2, 4, and 8)	8	29
5	Variable (0.25, 1, 2, 4, and 8)	0[a]	44
6	Variable (0.25, 1, 2, and 4)	4	22
7	Variable (0.25, 1, and 2)	2	20
8	Variable (0.25, 1, 2, 4, and 8)	0[a]	43

[a] 0 indicates that the reinforcer was delivered immediately after a correct choice.

sure used here, log d, was proposed by Davison and Tustin (1978) and has been used in the analysis of much DMTS data, including those of White and Bunnell-McKenzie (1985). Log d is, theoretically, a response-bias-free measure of stimulus discrimination that is computed as half the difference between logarithms of ratios of responses to the comparison stimuli following each sample stimulus. That is,

$$\log\, d = \frac{1}{2}\left[\log\left(\frac{c_1}{c_2}\right) - \log\left(\frac{c_3}{c_4}\right)\right], \qquad (1)$$

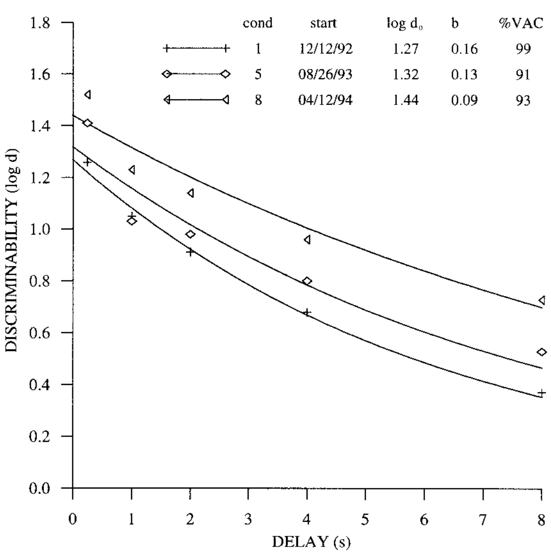

Fig. 1. The log d values, derived from Equation 1 and averaged across birds, for the three replications of the standard variable-delay condition (Conditions 1, 5, and 8), all 8 months apart, as functions of the delay to choice. The exponential functions were fitted using Equation 2, and the parameters of the fitted functions are shown on the figure.

where c_1 and c_2 are the total correct and error responses, respectively, following one sample stimulus, and c_3 and c_4 are the total error and correct responses, respectively, following the other sample. A series of log d estimates across a range of delay intervals can be fitted with a negative exponential function (after White & McKenzie, 1982). Namely,

$$\log\, d_t = \log\, d_0 \cdot \exp^{-bt}, \qquad (2)$$

where log d_0 is discriminability of the sample stimulus at no delay and b is the rate at which discrimination accuracy is attenuated with increasing delay interval.

In order to check the effects of increasing exposure to the DMTS task, the first variable delay (Condition 1) was repeated as Condition 5 and then again as Condition 8. As shown in Figure 1, each time the condition was repeated, the curve describing performance in that condition was higher and flatter, that is, log d_0 increased and b was smaller. There is a greater difference between the data from the second and third replications than between those from the first and second. The decreasing b values show that there was relatively more improvement in accuracy at the longer, as compared with the shorter, delay intervals. Table 3 shows that, from the averaged first and second determinations (Conditions 1 and 5) to the third determination (Condition 8), Subjects 71, 72, and 73 improved accuracy at all delay intervals (higher log d_0 and similar b), and Subjects 75 and 76 improved accuracy at the longer delay intervals (similar or slightly lower log d_0 and smaller b).

Log d values were averaged across the first and second standard variable-delay condi-

Table 3

The parameters of the fitted exponential functions (Equation 2) for each bird.

Bird	log d_0	b	% VAC
Conditions 1 and 5 (variable delay)			
71	1.10	0.13	94
72	1.36	0.10	98
73	1.05	0.34	63
75	1.26	0.18	91
76	1.64	0.12	98
M	1.26	0.14	97
Conditions 2 and 4 (variable delay with 8-s sample–reinforcer interval)			
71	0.80	0.06	94
72	0.87	0.09	78
73	0.40	0.04	44
75	0.70	0.08	77
76	0.83	0.07	45
M	0.72	0.07	87
Condition 3 (fixed delay)			
71	1.32	0.11	97
72	1.55	0.14	90
73	1.21	0.30	91
75	1.02	0.10	76
76	1.55	0.15	95
M	1.31	0.14	93
Condition 4 (variable delay with 8-s sample–reinforcer interval)			
71	1.10	0.08	55
72	0.96	0.06	64
73	0.58	0.05	81
75	0.74	0.06	51
76	1.14	0.11	66
M	0.90	0.07	92
Condition 5 (variable delay)			
71	1.27	0.11	91
72	1.41	0.11	94
73	1.42	0.51	65
75	1.16	0.13	92
76	1.64	0.09	92
M	1.32	0.13	91
Condition 6 (variable delay with 4–s sample-reinforcer interval)			
71	1.79	0.21	76
72	1.23	0.03	32
73	0.75	0.16	71
75	0.91	0.12	94
76	1.22	0.10	93
M	1.17	0.12	92
Condition 7 (variable delay with 2-s sample–reinforcer interval)			
71	incalculable, due to infinite log *d* values		
72	1.53	0.21	98
73	1.69	0.57	99
75	1.57	0.34	74
76	1.70	0.21	98
M	1.62	0.26	95
Condition 8 (replication of Condition 1)			
71	1.88	0.13	98
72	1.45	0.06	90
73	1.59	0.38	67
75	1.22	0.09	53
76	1.49	0.05	44
M	1.44	0.09	93

tions (1 and 5) and also across the first and second 8-s sample–reinforcer interval conditions (2 and 4), in a fashion similar to White and Bunnell-McKenzie's (1985) study. These log *d* values, together with those for the fixed delays and the final replication of the standard variable delay, all averaged across birds, are plotted as a function of delay to choice in Figure 2. Individual negative exponential curve fits and parameters are given in Table 3. Figure 2 shows log d_0 values systematically decreasing with increasing delay interval. The data are reasonably well fitted by negative exponential functions, that is, the percentage of

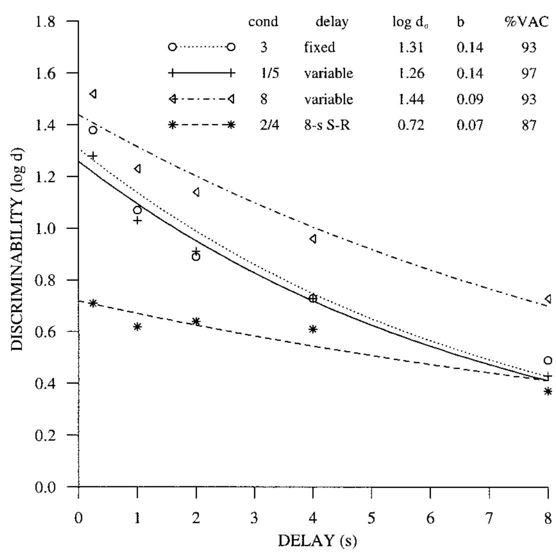

Fig. 2. The log *d* values, derived from Equation 1, for the three different types of DMTS conditions, averaged across subjects, as functions of the delay to choice. Shown are the data from Condition 3 (fixed delay, unfilled circles), the averaged data from Conditions 1 and 5 (standard variable delays, crosses), and the averaged data from Conditions 2 and 4 (variable delays with 8-s sample–reinforcer interval, asterisks). The exponential functions were fitted using Equation 2, and the parameters of the fitted functions are shown on the figure.

variance in data accounted for by the fitted functions (%VAC) ranged from 87% to 97% for the various conditions. For individual subjects, curve fits ranged from 44% to 98%VAC (Table 2). For the group data, curves describing performance from the first two standard variable-delay conditions (Conditions 1 and 5) and from the fixed-delay condition (Condition 3) are similar, with log d_0 = 1.26 and b = 0.14 for the variable delays and log d_0 = 1.31 and b = 0.14 for the fixed delays. The curve fitted to log d values from the two 8-s sample–reinforcer interval conditions (Conditions 2 and 4) is much lower (log d_0 = 0.72) and largely flat (b = 0.07), but meets the curves of the other conditions at the 8-s delay interval. The final replication of the standard variable delay (Condition 8) gave the highest curve (log d_0 = 1.44, b = 0.09).

Table 3 shows that these trends are representative of individual subjects' data. All subjects produced similar log d_0 and b values for the first two standard variable-delay conditions (1 and 5) and the fixed-delay condition (4), and in every case the 8-s sample–reinforcer interval conditions (2 and 4) resulted in smaller values of both parameters than the fixed-delay and standard variable-delay conditions. Subject 73's data follow this pattern but are notably different from those of the other hens in two respects. First, her matching accuracy dropped more sharply than any of the other birds with both the fixed and variable delays (high values of b); second, her accuracy with the 8-s sample–reinforcer interval was consistently low (i.e., low values shown for both parameters).

Log d values averaged across all the birds' data for the 8-, 4-, and 2-s sample–reinforcer interval conditions, with curves fitted, are shown in Figure 3. In each of these, the sample–reinforcer interval was fixed at the longest delay to choice: 8 s in Condition 4, 4 s in Condition 6, and 2 s in Condition 7. The log d values decreased with increasing delay interval in every condition and are well fitted by the curves (92% to 95%VAC). The curves become progressively higher and steeper from the 8-s sample–reinforcer interval (log d_0 = 0.9, b = 0.07), through the 4-s sample–reinforcer interval (log d_0 = 1.17, b = 0.12), to the 2-s sample–reinforcer interval (log d_0 = 1.62, b = 0.26). This trend is representative of each individual bird, as shown in Table 3,

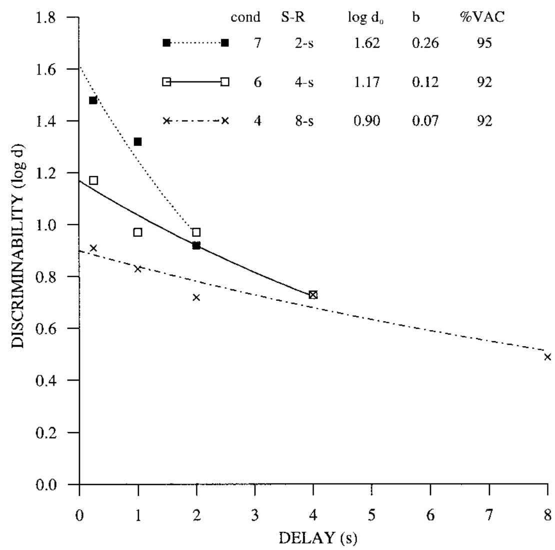

Fig. 3. The average log d values, derived from Equation 1, from the three variable-delay conditions with sample–reinforcer intervals of 2 s (Condition 7), 4 s (Condition 6), and 8 s (Condition 4), as functions of the delay to the choice. The exponential functions were fitted using Equation 2, and the parameters of the fitted functions are shown on the figure.

except that b values for Subjects 72 and 76 were slightly lower for the 4-s than for the 8-s condition.

DISCUSSION

The present procedure, unlike that of McCarthy and Davison (1991), allowed assessment of changes in log d_0 with changes in the sample–reinforcer interval. The fitted functions for the three constant sample–reinforcer conditions form an orderly pattern, becoming progressively lower and flatter (log d_0 and b both decrease) from the 2-s (Condition 7) to the 4-s to the 8-s sample–reinforcer interval (Conditions 2 and 4). Although the improvement in accuracy over time must have contributed to the change in log d_0, it does not account for all of it. If the increases in log d_0 with decreases in sample–reinforcer interval were solely a product of general improvement in accuracy, then one would have expected the data from the 8-s and 4-s sample- reinforcer intervals to be above the first standard variable-delay data. However, log d_0 values from the 8-s sample–reinforcer interval conditions (2 and 4) are lower than those from the first standard variable-delay condition (1), and those from the 4-s sample–reinforcer interval condition (6) are lower than those from both previous standard variable-delay conditions (1 and 5). The changes in b with successive sample–reinforcer interval conditions are in the reverse direction from the changes in b seen over the standard variable-delay conditions. Thus, the observed changes in b over the standard variable-delay conditions would work to moderate the effect seen with changes in sample–reinforcer interval.

Given the changes in accuracy over time, the 8-s sample–reinforcer interval data (Conditions 2 and 4, Figure 2) were compared with those from the variable-delay conditions closest in time. This comparison shows the effect of delay to reinforcement in a DMTS task. The curve for the 8-s sample–reinforcer interval data is low and flat, because matching accuracy at the shorter delay intervals was not much higher than that at the longest delay interval. The values of b are lower than those from the standard variable-delay conditions (1 and 5). Because the only difference was that reinforcement was held at a constant 8 s from sample termination, these data provide strong support for McCarthy and Davison's (1991) findings; forgetting over time is partly accounted for by the delay to reinforcement from the beginning of the delay interval. Unlike the McCarthy and Davison study, the design of the variable delay here, with the constant 8-s sample–reinforcer interval, allows an estimate of the relative influences of both the sample–choice interval and the sample–reinforcer interval on maintaining correct matching. That is, if the constant 8-s sample–reinforcer interval had had no effect on the standard variable-delay function, then it would be arguable that the sample–reinforcer interval has no influence on correct matching. If, instead, the delay function had been completely flat—that is, if matching accuracy at all shorter sample–choice intervals had been the same as at the 8-s interval—then it could be argued that sample–reinforcer interval entirely accounts for the standard delay functions observed in DMTS, and that increasing the sample–choice interval has no independent effect. The data from the 8-s sample–reinforcer conditions (2 and 4) in Figure 2 show that sample–reinforcer interval is by far the greater determinant and that the length of the sample–choice interval has only a small independent effect on matching accuracy.

The increases in log d_0 with decreasing sample–reinforcer interval would be predicted by a delay-reduction account of performance under a DMTS task (Wixted, 1989), because the average time to reinforcement decreases as this interval decreases. However, the points from the 8-, 4-, and 2-s sample–reinforcer conditions that did not involve a choice-reinforcer delay (i.e., from the longest delay interval in each condition) land reasonably close to the standard variable-delay curves closest in time. This effect is clearly seen in Figure 2 for the 8-s data. The fact that these data are similar to those from the standard variable-delay data suggests that accuracy at these delays was not influenced by the overall lower rate of reinforcement in these sessions. This result stands against the argument that responding is affected by an average reinforcer delay. It suggests that each sample–choice–reinforcer chain can be manipulated independently of the others in the session, and lends strong support to White and Cooney's (1996) finding that altering the probability of reinforcement at one delay interval alters performance at that interval, independent of performance at other intervals.

A delay-reduction account of performance predicts the effects of the sample–choice interval to be less extreme with shorter sample–reinforcer intervals (both sample and choice stimuli signal a reduction in the delay to reinforcement). However, this was not found, because b increased as sample–reinforcer interval decreased, with the 2-s sample–reinforcer interval data generally giving larger b values than any of the other data (Condition 7, Table 2). No current model of performance under DMTS predicts this finding. At the shortest choice–reinforcer delay with the 2-s sample–reinforcer interval (Condition 7), accuracy was generally higher than at the same sample–choice delay in the following standard variable-delay condition (Condition 8, as illustrated by the mean data in Figures 1 and 3). This finding suggests that there might be some phenomenon at work other than the delay to reinforcement, because it would not be expected that this delay would improve performance. Chung (1965) provides a possible explanation for differential effects of short reinforcer delays. He suggested that in a short delay to reinforcement, the subject has time to move towards the feeder during the delay and so may be ready to eat immediately when the food magazine is operated and thus obtain more food. Thus, he argued, short delays could increase the efficacy of the reinforcer. It is not clear whether increasing reinforcer magnitude will increase accuracy under DMTS, but it is possible, if Chung is correct, that short delays to reinforcement might function somewhat differently from longer delays. The fact that the b values from the 4-s sample–reinforcer interval data are usually larger than those from the 8-s sample–reinforcer interval means that the 4-s sample–reinforcer interval decreased accuracy proportionally less at shorter delays than did the 8-s one (Table 2). This may indicate that there are additional complicating effects involved in the 4-s sample–reinforcer interval, and the phenomenon described by Chung might also have an effect at this delay. Whether or not differing magazine access times give rise to such an effect could be examined by using a procedure in which the food hopper is raised for a period timed from when the animal has moved to it. This would make sure that all reinforcers were of equal duration and that movements towards the hopper prior to its operation would not alter the magnitude of reinforcement.

Comparison between the results of the fixed and variable delays (Figure 2) is confounded by the increasing accuracy in the standard variable-delay conditions over the experiment (Figure 1). Over these three conditions, log d_0 increased while b tended to decrease, and, although accuracy was initially lower with the variable delays than with the fixed delays, it was higher by the end of the experiment. If the fixed delay (Condition 3) is compared to the bracketing variable delay (Conditions 1 and 5, conducted before and after), there appears to be little difference. White and Bunnell-McKenzie (1985) found no improvement in accuracy for their variable-delay sessions conducted before and after the fixed-delay conditions. It is possible that their pigeons, with much previous experience of variable delays, may have already reached asymptotic performance with variable delays. The fixed delays were conducted only once in both studies, so it is not possible to determine whether performance was becoming increasingly accurate under these conditions.

There is no current model of nonhuman memory that accounts for all of the present results, although most of the present data fall into line with White's (1993) (Footnote 1) direct remembering theory. According to this theory, the temporal distance between the sample and comparison stimuli is, in principle, no different from a physical distance between stimuli. Thus, accuracy at any sample–choice interval can be maintained, strengthened, or punished independent of accuracy at any other sample–choice intervals in a session. In the present study, imposing a constant sample–reinforcer interval resulted in differing levels of matching accuracy for sample–choice intervals that involved a choice–reinforcer delay, independent of sample–choice intervals not involving a reinforcer delay. For example, this independence is shown where an 8-s sample–reinforcer interval decreased accuracy with a 4-s sample–choice interval, whereas accuracy with an 8-s sample–choice interval remained comparable to that under the standard DMTS conditions. This aspect of the present results is not predicted by the delay-reduction hypothesis (Wixted, 1989), although this hypothesis would imply the decrement in log d_0. No theory accounts for the observed decrement in b with increases in sample–reinforcer interval. This decrement may be confounded, however, by the possible effect of short delays to reinforcement, as described by Chung (1965).

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Received February 15, 1996
Final acceptance October 1, 1997